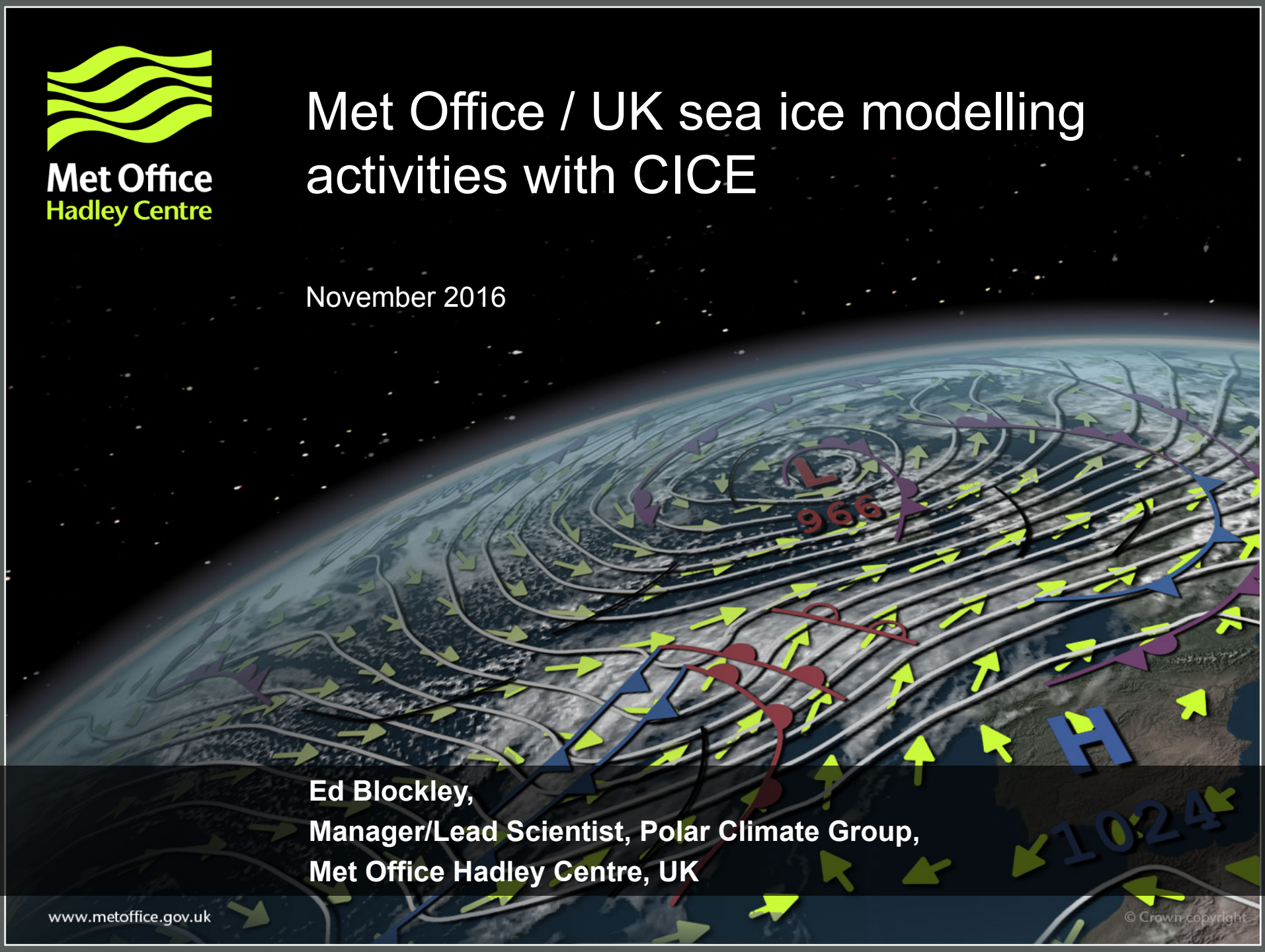
Met Office / UK sea ice modelling activities with CICE

November 2016



Ed Blockley,
Manager/Lead Scientist, Polar Climate Group,
Met Office Hadley Centre, UK

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Contents

- Met Office function & systems
- Met Office / UK use of CICE
- Met Office / UK partnerships and users
- UK CICE development
- Potential consortium requirements

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Met Office

HQ: Exeter, UK

- **UK's national/public weather service**
  - **Flood Forecasting Centre**
  - **Space Weather Centre**
- **Hadley Centre for climate change research**
  - **Climate services/consultancy**
- **UK MOD (Royal Navy, RAF, Army)**
- **Commercial business (oil & gas, national grid etc.)**

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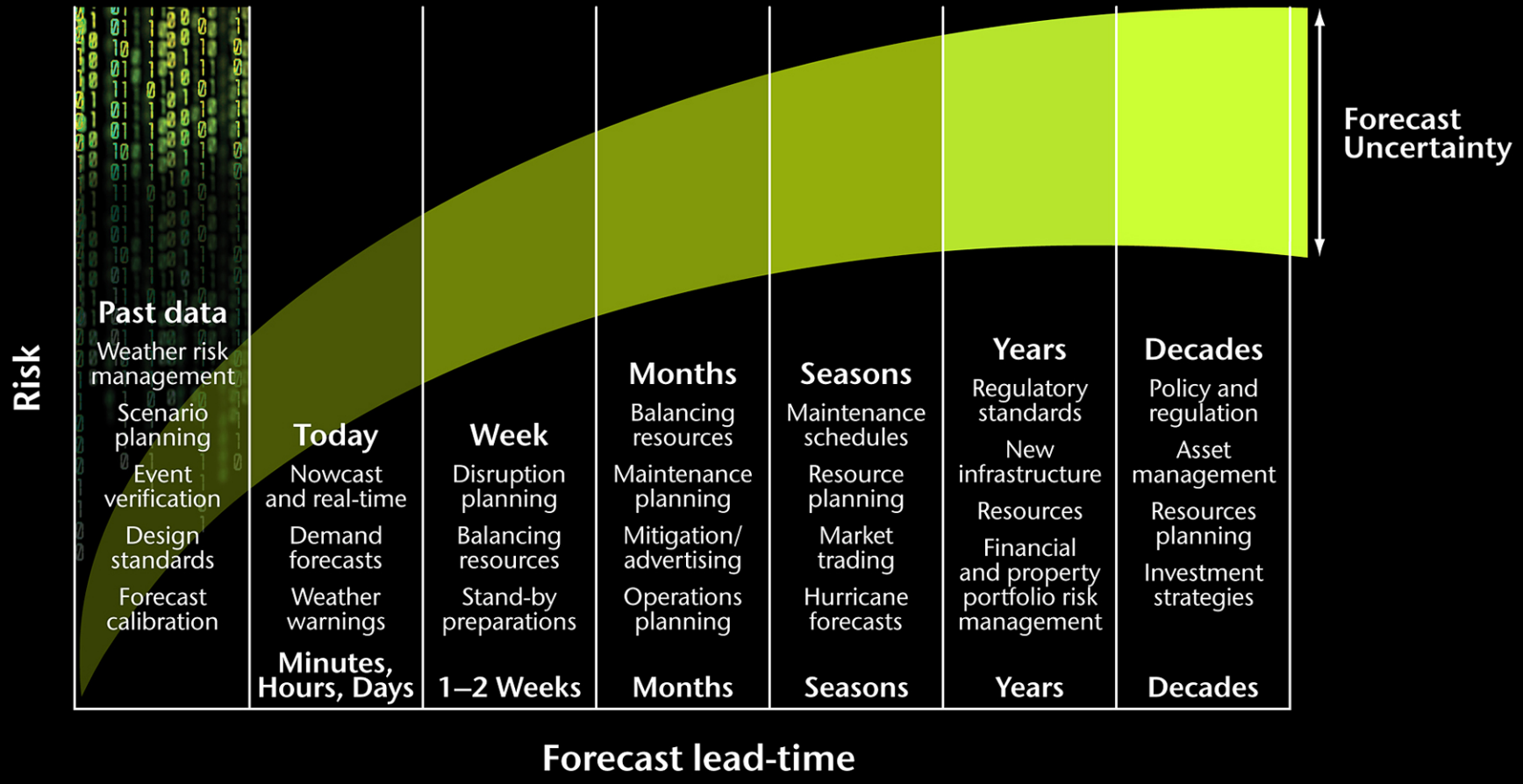
Seamless forecasting

Across a range of timescales



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Global Physical Modelling

Unified Prediction across Timescales

Met Office

Hours Days Weeks Months Seasons Decades Centuries

1/12°

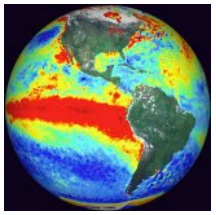
NWP - Atmosphere, Ocean, Waves

Deterministic

1/4°

MOGREPS

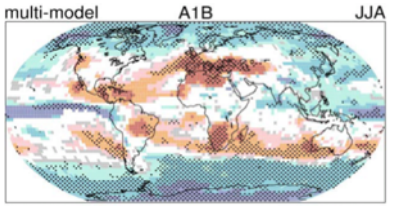
Ensembles



GloSea

Decadal

1°



Climate & Earth System Model

Component Models
GA7, GL7, GO6, GSI8

Coupled AOIL Model
GC3.0

Met Office Unified Model™ Global Atmosphere

JULES Global Land

NEMO Global Ocean

CICE Global Sea Ice

WaveWatch III Global Waves

Relevant systems:

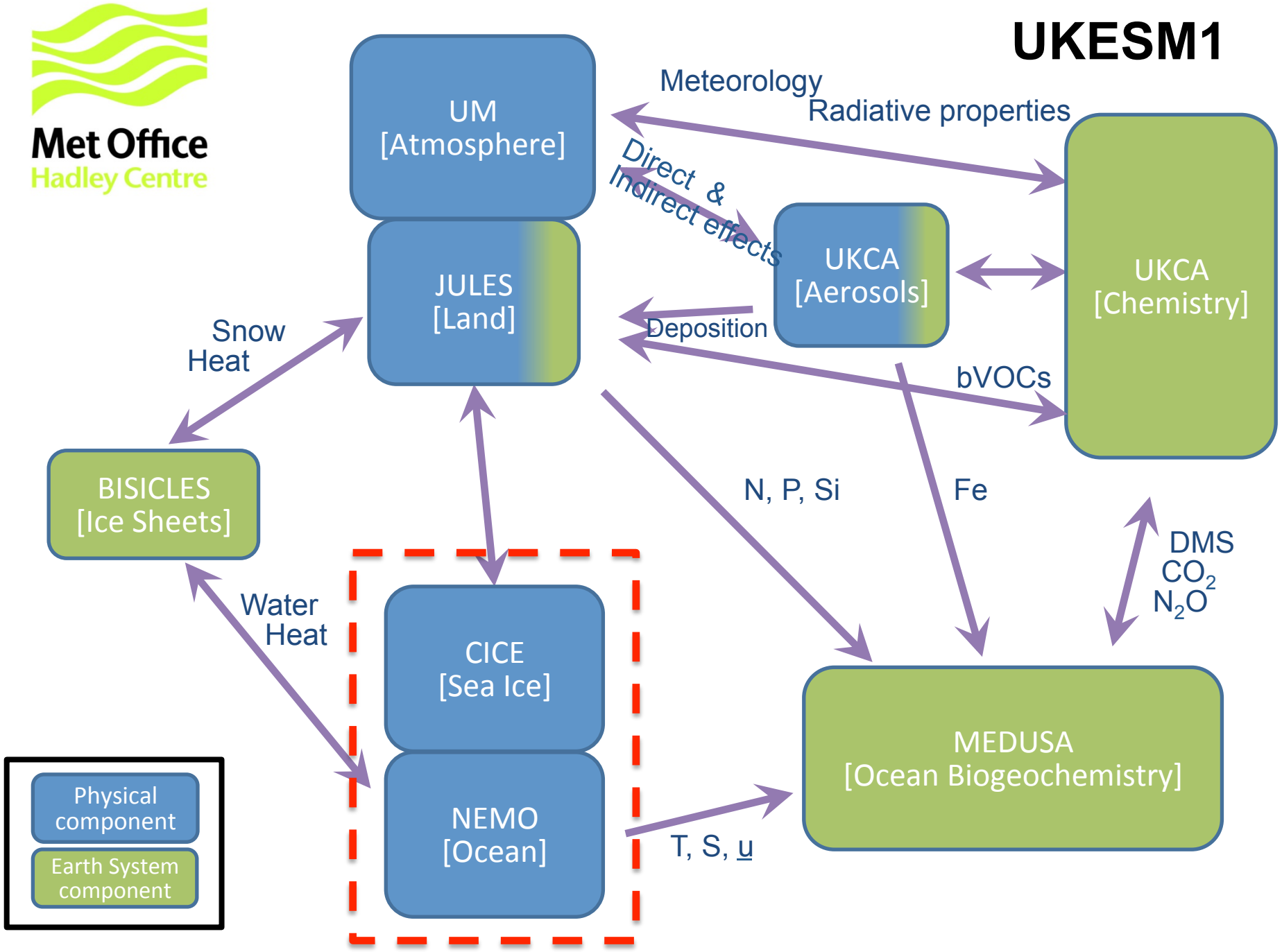
- **FOAM**:
  - Operational ocean-sea ice analysis and forecasting system
  - NEMO ocean, CICE sea ice, NEMOVAR 3DVar
  - Global (1/4°) & N. Atlantic (1/12°)
  - Run daily at the Met Office
  - (Coupled NWP being developed)

- **GloSea**:
  - Operational seasonal coupled forecasting system
  - NEMO-CICE coupled to UM (atmos) & JULES (land)
  - Global: atmos-land (~60km); ocean-sea ice (1/4°)
  - Initialised using FOAM ocean & sea ice analyses
  - Run daily at the Met Office: 1800 days simulated per day

Relevant systems:

- **HadGEM3**:
  - Coupled physical climate model
  - CICE coupled with NEMO, MetUM, JULES
  - Surface exchanges calculated in JULES land surface code
  - Basis for GloSea seasonal forecasts
  - UK's contribution towards CMIP & IPCC
  - Resolutions (H – M – L):
    - Atmosphere-land (25km – 60km – 135km)
    - Ocean-sea ice (1° – 1/4° – 1/12°)
- **UKESM**:
  - Extending HadGEM3 physical climate model
  - Including: atmospheric chemistry (UKCA); ocean biogeochemistry (MEDUSA); ice sheets (BISICLES)
  - Developed jointly with UK academia (NERC)

UKESM1


Met Office
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UM
[Atmosphere]
Meteorology
Radiative properties
Direct &
Indirect effects
UKCA
[Aerosols]
UKCA
[Chemistry]
JULES
[Land]
Snow
Heat
Deposition
bVOCs
BISICLES
[Ice Sheets]
N, P, Si
Fe
DMS
CO_2
N_2O
Water
Heat
CICE
[Sea Ice]
MEDUSA
[Ocean Biogeochemistry]
NEMO
[Ocean]
T, S, u
Physical component
Earth System component

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Met Office UM Partnership & users

UK & International

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Unified Model Partnership

- A global enterprise comprising operational and research centres
- Use and development of seamless modelling system for weather and climate applications

- Enables scientific and technical collaboration with a shared suite of earth system modelling software
- Across a range of modelling and science issues relevant for weather and climate prediction

MetUM:
Core and Associate Partners

MetUM: Core and Associate Partners

Core Partners	
Bureau of Meteorology	**Australia**
CSIRO	**Australia**
Ministry of Earth Sciences	**India**
NCMRWF	**India**
NIWA	**New Zealand**
KMA	**South Korea**
Met Office	**UK**
NCAS	**UK**

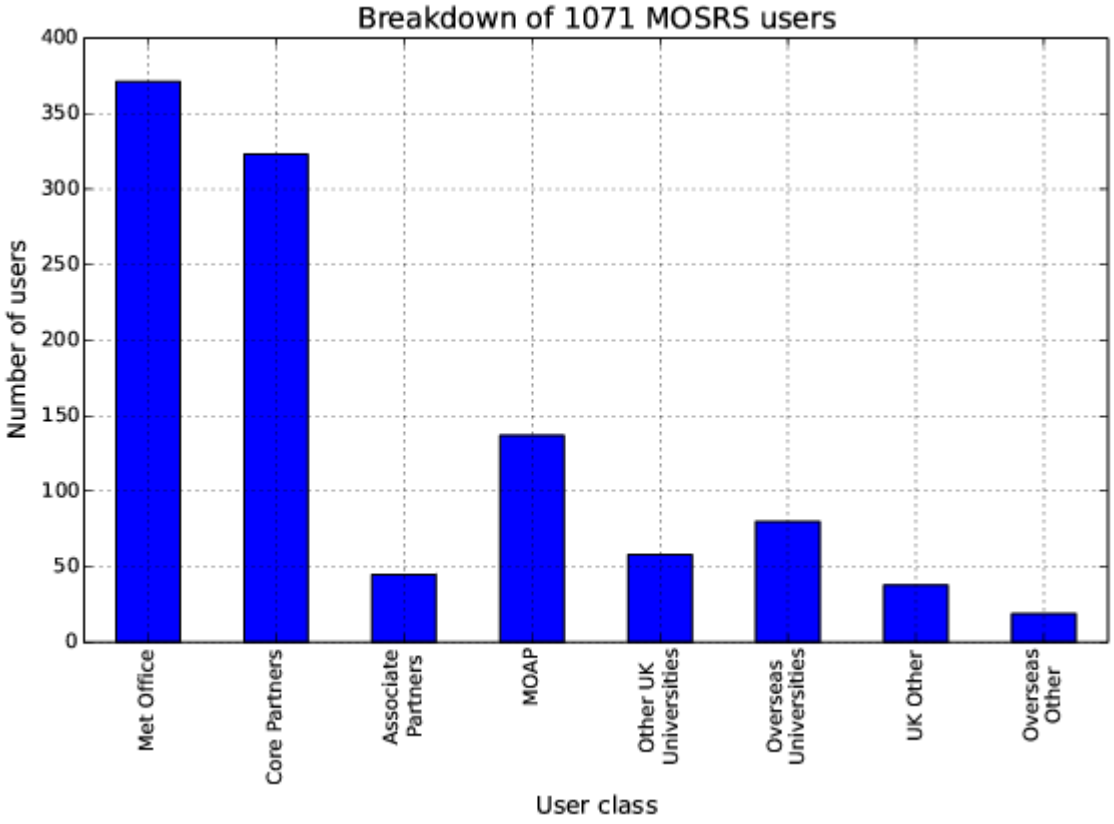
Associate partners	
PAGASA	**Philippines**
ICM	**Poland**
SAWS	**South Africa**
US Air Force	**USA**

Met Office Science Repository Service (MOSRS)

https://code.metoffice.gov.uk/trac/home

- Met Office Science Repository (MOSRS) underpins much of the scientific collaboration between Met Office and its partners.
- Cloud based capability that is hosted by a UK government approved supplier accessible by Met Office and collaborating scientists.
- Science code is held on subversion repositories
- Trac environments exist for each project that:
  - facilitate code development work flow that is managed using an issue tracker
  - permit knowledge sharing using a Trac wiki
- To date:
  - 34 project exist together with 21 svn repositories
  - Over 1000 users (1071 as of May 2016)

Met Office Science Repository Service (MOSRS)



Benefits

- Increased technical & scientific collaboration across the Partnership.
- Greater likelihood of pull-through of collaborative science changes by using common code.
- Increased robustness in code base through wider code testing coverage + hardware.

- Primarily UM-JULES
- Coupled model users rising

Summary of users as of May 2016

CICE & SRS

- Plans to move Met Office in-house CICE repository into SRS
- Providing code to UK partners as part of UKESM
- Increasing international use of HadGEM3 / GloSea systems
- To be maintained by UM Partnership and core infrastructure groups

- Details still being finalised
- To complete over coming months

UK Global Ocean and Sea Ice configuration development

JSIMP

- Global Sea Ice configurations are developed jointly between Met Office and academia (NERC: Natural Environment Research Council)
- These activities are performed under the Joint Weather and Climate Research Programme (JWCRP):
  - **JSIMP : Joint Sea Ice Modelling Programme**
    - Met Office, CPOM (Reading & UCL), NOC and BAS
    - Co-chaired by Danny Feltham (CPOM) & Ed Blockley (Met Office)

- Met Office systems are users of the Global Ocean (GO) and Global Sea Ice (GSI) configurations developed by JOMP & JSIMP
- Parallel programme for ocean development (JOMP)

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Current/past UK Contribution to CICE

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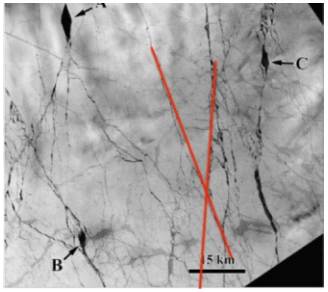
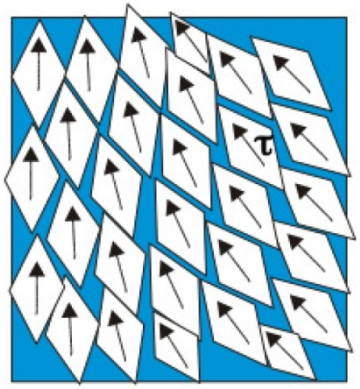
CPOM CICE developments



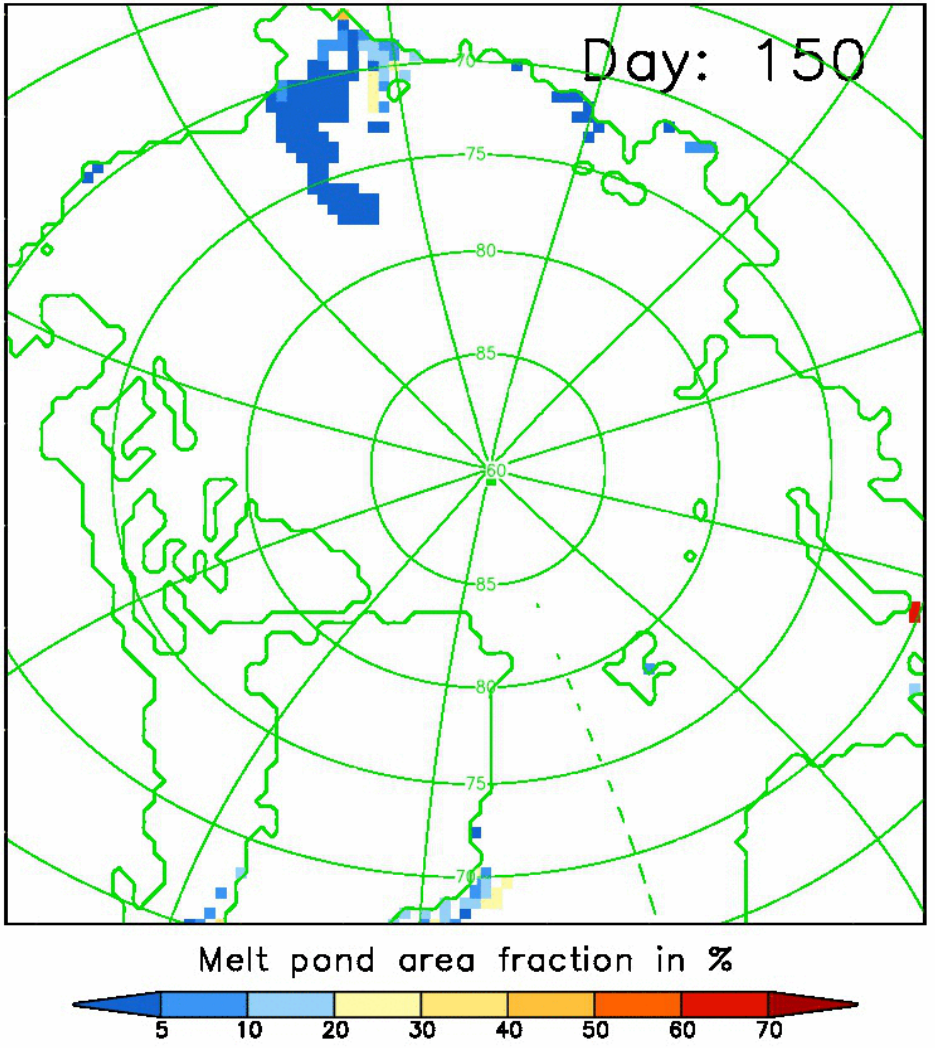


- Physics functionality developed by CPOM modelling group (D. Feltham, U. Reading, UK) and included into CICE:
  - Prognostic melt ponds (radiative and freshwater impacts)
  - Prognostic form-drag (ocean & atmosphere)
  - Anisotropic rheology
- Further developments in the pipeline:
  - Melt pond re-freezing (latent effects and thermodynamics?)
  - Under-ice melt ponds
  - Frazil ice model
  - Wave-ice interaction & MIZ processes (granular physics)

CPOM contributions to CICE

Group leader: Danny Feltham

Melt ponds

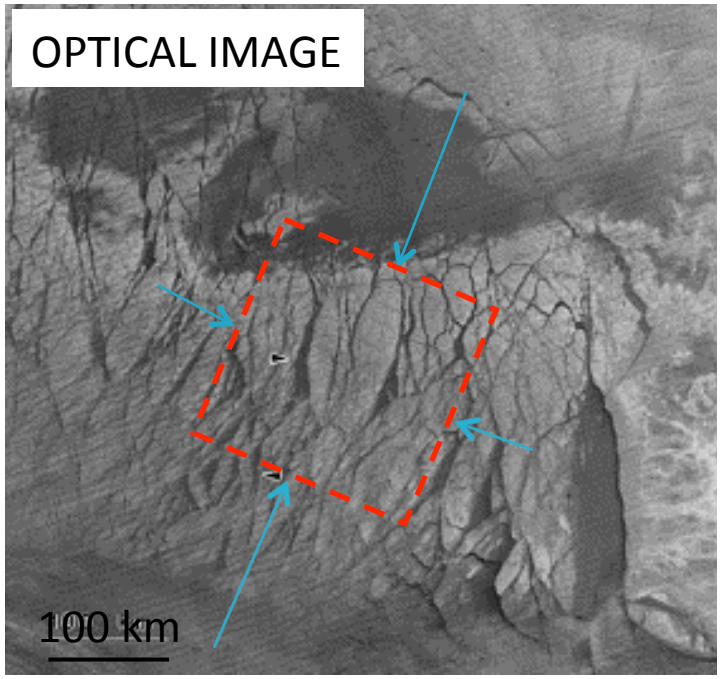


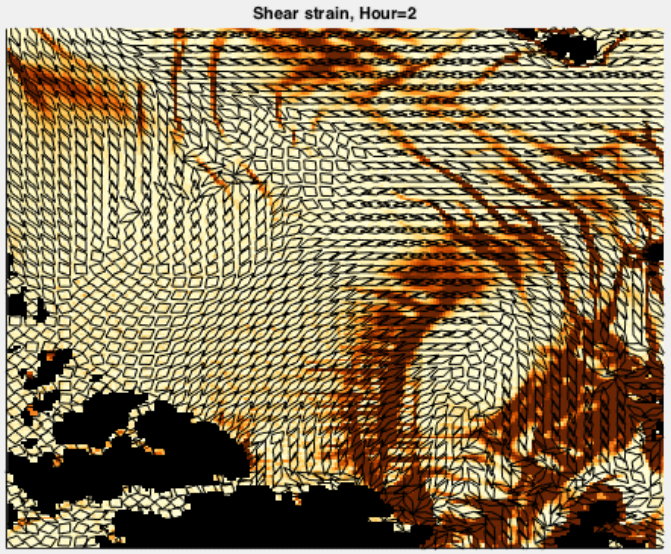
CPOM developed high resolution, high fidelity models of melt ponds derived from basic physics and tested with observations.

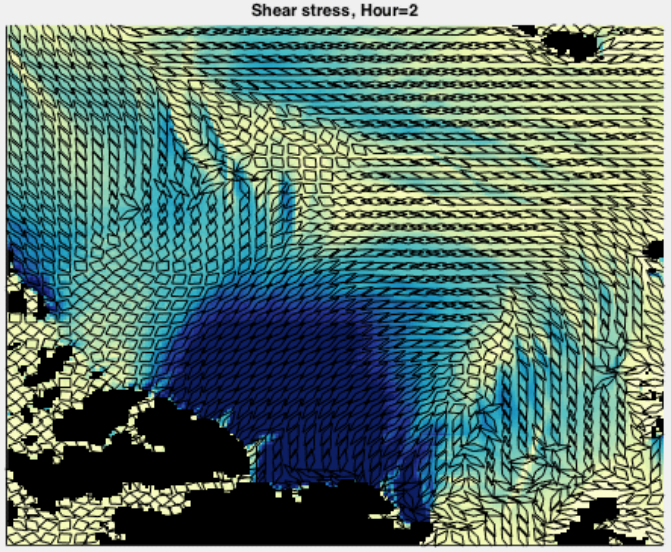
CPOM developed a melt pond parameterisation now included within CICE and within HadGEM.

Melt pond scheme forms basis of skilful (& successful) predictions of Arctic sea ice minima.

Anisotropic sea ice rheology







Since satellite imagery became widely available it was widely recognised the ice cover was anisotropic, but developing a theory was tough.

Based on many studies, CPOM developed the first Anisotropic sea ice rheology.

The Elastic Plastic Anisotropic rheology is now included in CICE.

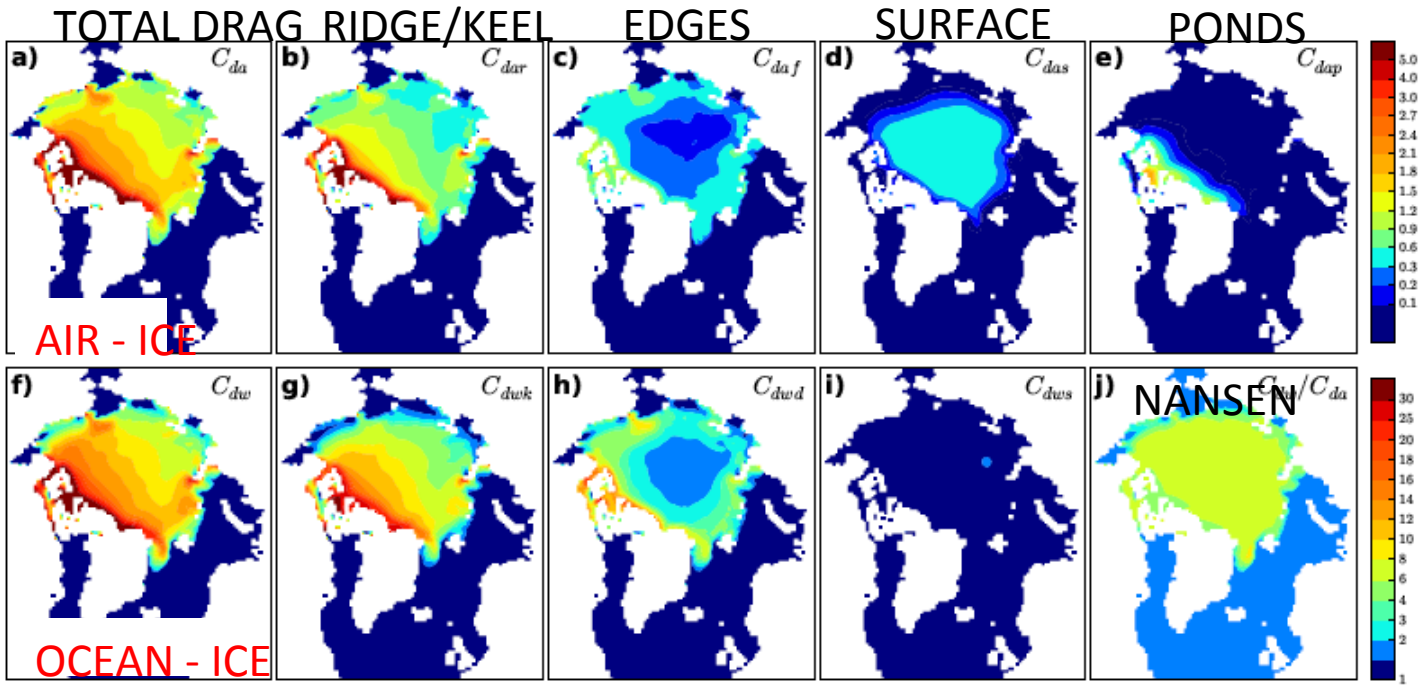
Form drag

CPOM introduced parameterisation of form drag, accounting explicitly for form drag from ridges, keels, floe edges.

Shown to have large impact on spatial pattern and timing of momentum transfer between air, ice and ocean.

This parameterisation now included in CICE.

Map of drag coefficients, average September 1990-2007



- Spatial variation of total drag coefficient of a factor of 4
- Ridges/keels form drag still dominates.. but floe edge drag becomes significant

Other funded stuff in the pipeline..

- New frazil ice parameterisation already developed, included in local CICE branch
- Variable mixed layer depth
- Explicit representation of melt ponds in 1D thermodynamic model: melt pond refreezing, under ice melt ponds,..
- Crack healing in anisotropy model
- Internal wave drag

Plus a lot more that is currently speculative or unfunded.

NOTE on funding:

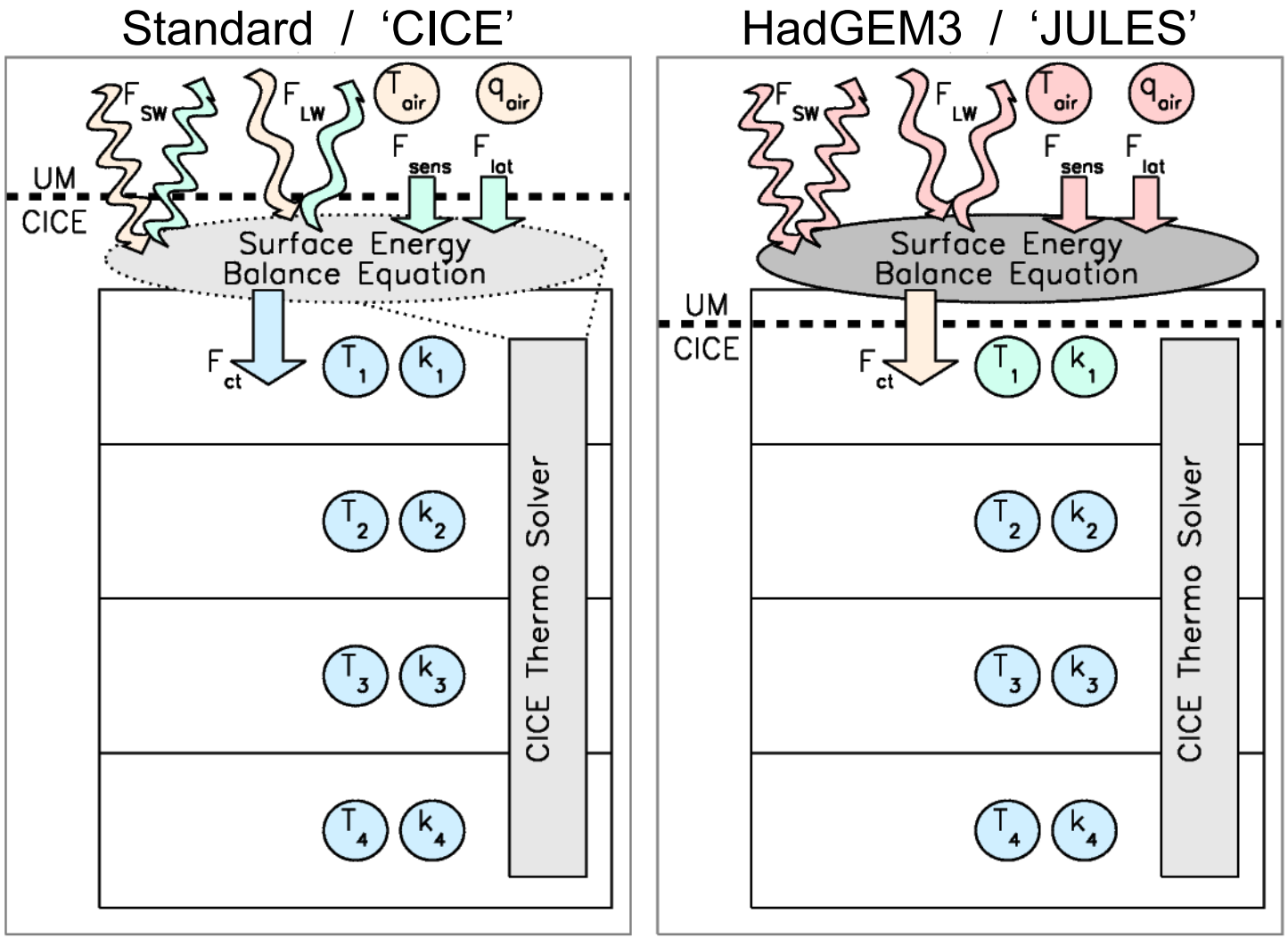
Model development is only fundable when needed to answer to large-scale science questions, which is typically motivated by UK climate needs.

Coupling to NEMO & HadGEM3

- Development & maintenance of coupling code to couple CICE with NEMO & HadGEM3

- **HadGEM3** (UM/JULES)
  - Code within JULES & CICE repositories (drivers/hadgem3)
  - Used by UK and UM Partnership collaborators
- **NEMO**
  - Code within NEMO & CICE
  - Used by UK and UM Partnership collaborators
  - Also by other NEMO-CICE users such as ECCC (Canada) & CMCC (Italy)

Coupling methodology



[West et al., 2016]

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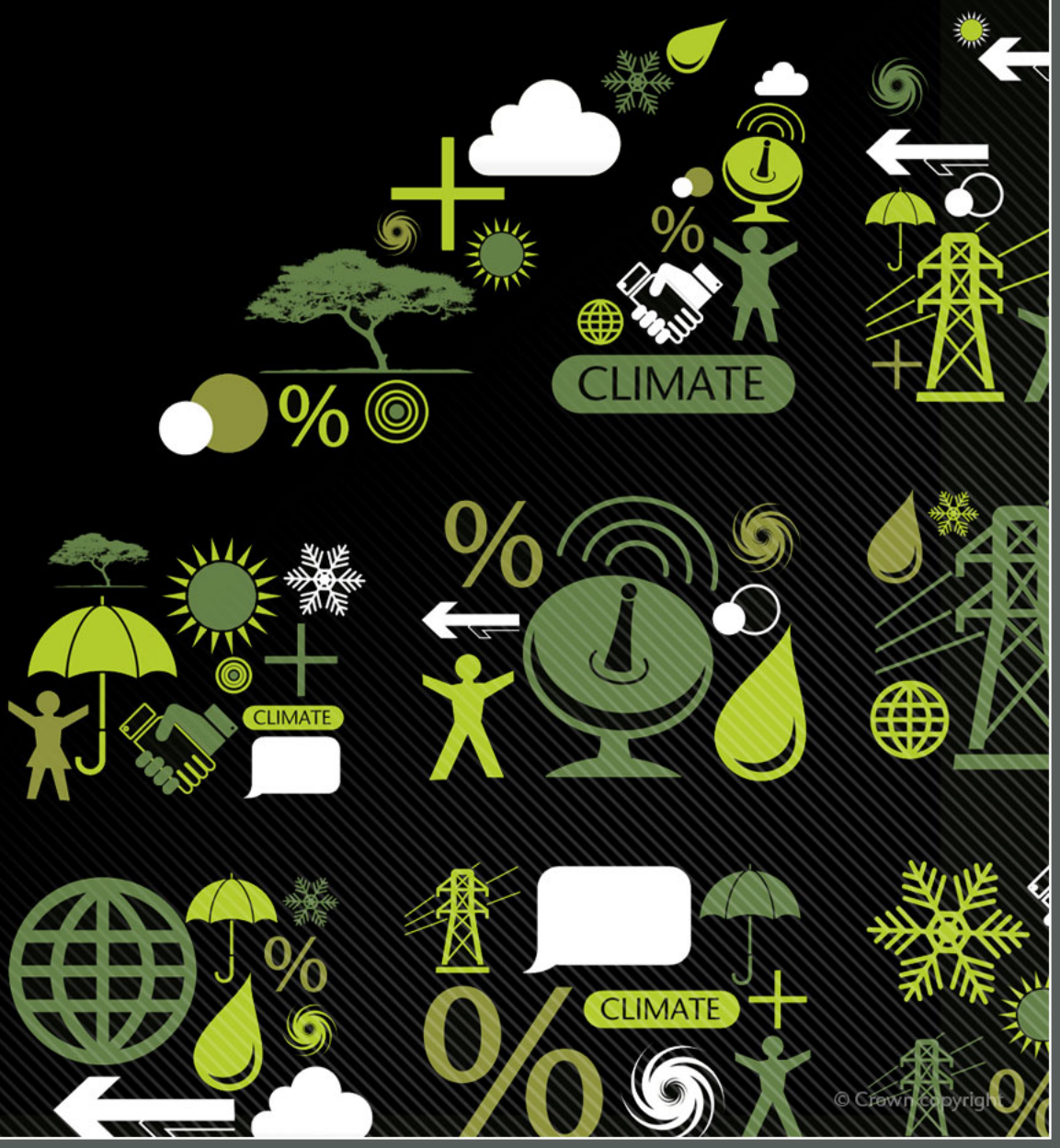
Consortium aspirations and contributions



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NEMO consortium model

- NEMO = Nucleus for European Modelling of the Ocean
- Developed/owned by consortium agreement
  - 6 members (operations & academia) from 3 countries (UK, France, Italy)
- Stable dedicated funding:
  - NEMO systems team (1 FTE per member)
  - Administration extra 1-2 FTE (Paris)
- Science R&D contributions additional
  - developers committee/coordination
  - development plan & working groups

NEMO consortium model

- Central repository in Paris (Trac/svn)
  - Branches for consortium member developments
  - Code accessible to all who register
  - Many more users from outside consortium countries/ organisations (inc. ECMWF, ECCC)

- Activity plan:
  - Coordination of R&D activities
  - 2-3 year road-map

Consortium aspirations

- Fully funded leadership – scientific & technical
  - High scientific quality
  - Rigorous technical testing/standards
- Multi-centre buy-in but with common direction
- Ability to share with UK collaborators & international partners
- Coupling to (and works with) NEMO & HadGEM3/JULES
- Involvement of CPOM group developments
- No restrictions on publication

Possible UK contributions

- Inclusion of future physics developments within CICE (developments themselves dependent on soft funding)
- Robust, fully maintained repository service (SRS) or mirror/backup if required
- Maintenance/development of coupling to NEMO and HadGEM3/JULES modelling systems
- Possible commitment?:
  CPOM 0.5 FTE (plus developments)
  Met Office 0.5 FTE (plus repository)

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- Text
- More Text

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Thank you for your attention.

Questions and answers?

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Met Office systems

With polar/high latitude capability

- UK's national weather service
  - Real-time atmosphere and flood forecasting [UM, MOGREPS, JULES]
  - Daily short-range atmosphere forecasting [UM]
  - Daily short-range wave forecasting [WW3]
  - SST & sea ice analyses [OSTIA]
- Hadley Centre for climate change research
  - Seasonal to decadal prediction [GloSea]
  - Climate prediction [HadGEM3]
  - Earth system & palaeoclimate modelling [UKESM1]
  - Satellite and in-situ observational products [EN3/4, HadISST]

Not Coupled

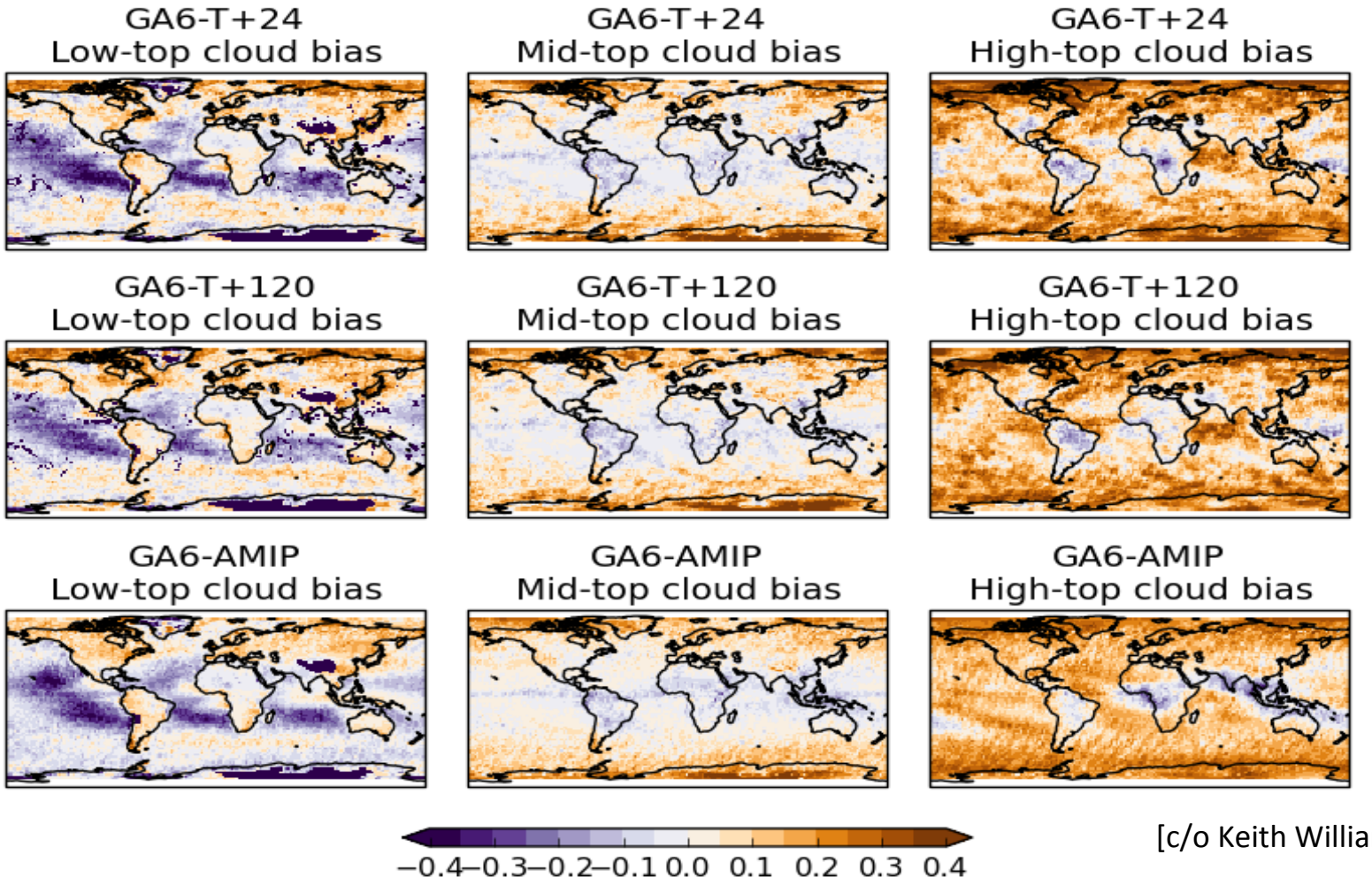
Coupled

Seamless forecasting

- Seamless development of models:
  - Allows time savings (e.g. fewer models to maintain)
  - However there are challenges (e.g. one size may not fit all)
- Biases/errors across the different systems (relatively) consistent
- Seamless development allows key problems to be addressed in a consistent manner:
  - Process Evaluation Groups (PEGs)
  - Across Weather, Climate & Foundation Science areas

Consistent biases in cloud cover

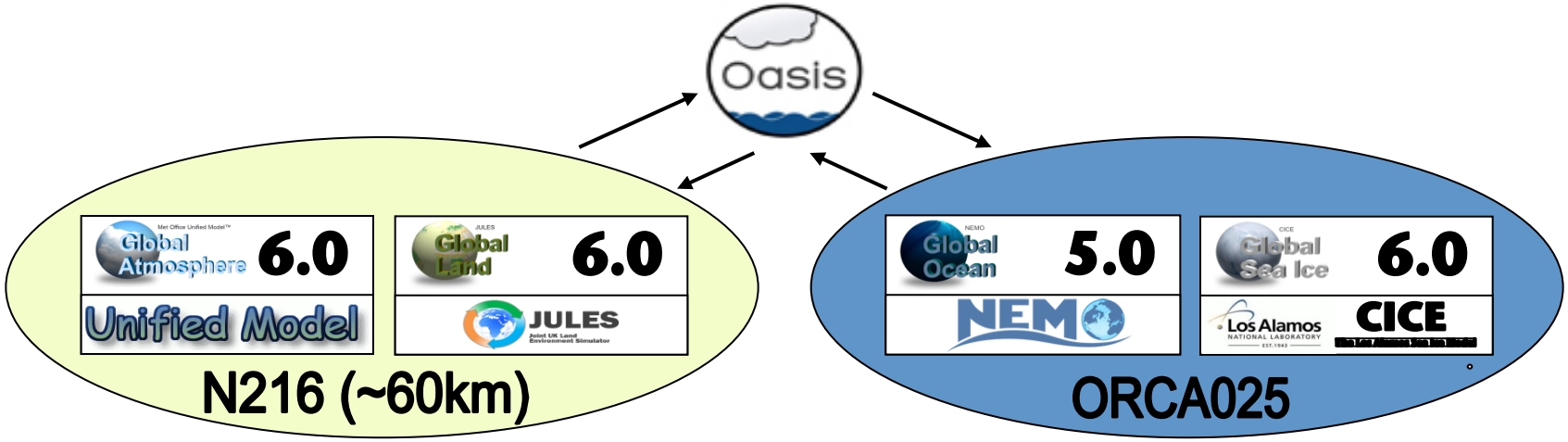
(against CALIPSO)



[c/o Keith Williams]

GloSea5 setup

GC2.0 Global Coupled modelling configuration



Resources required:

- 34,560 CPU hours per day
- 12.6 million CPU hours per year
- ~~4% of Met Office HPC~~
- 304 GB per day
- 108 TB per year
- 1800 days simulated per day

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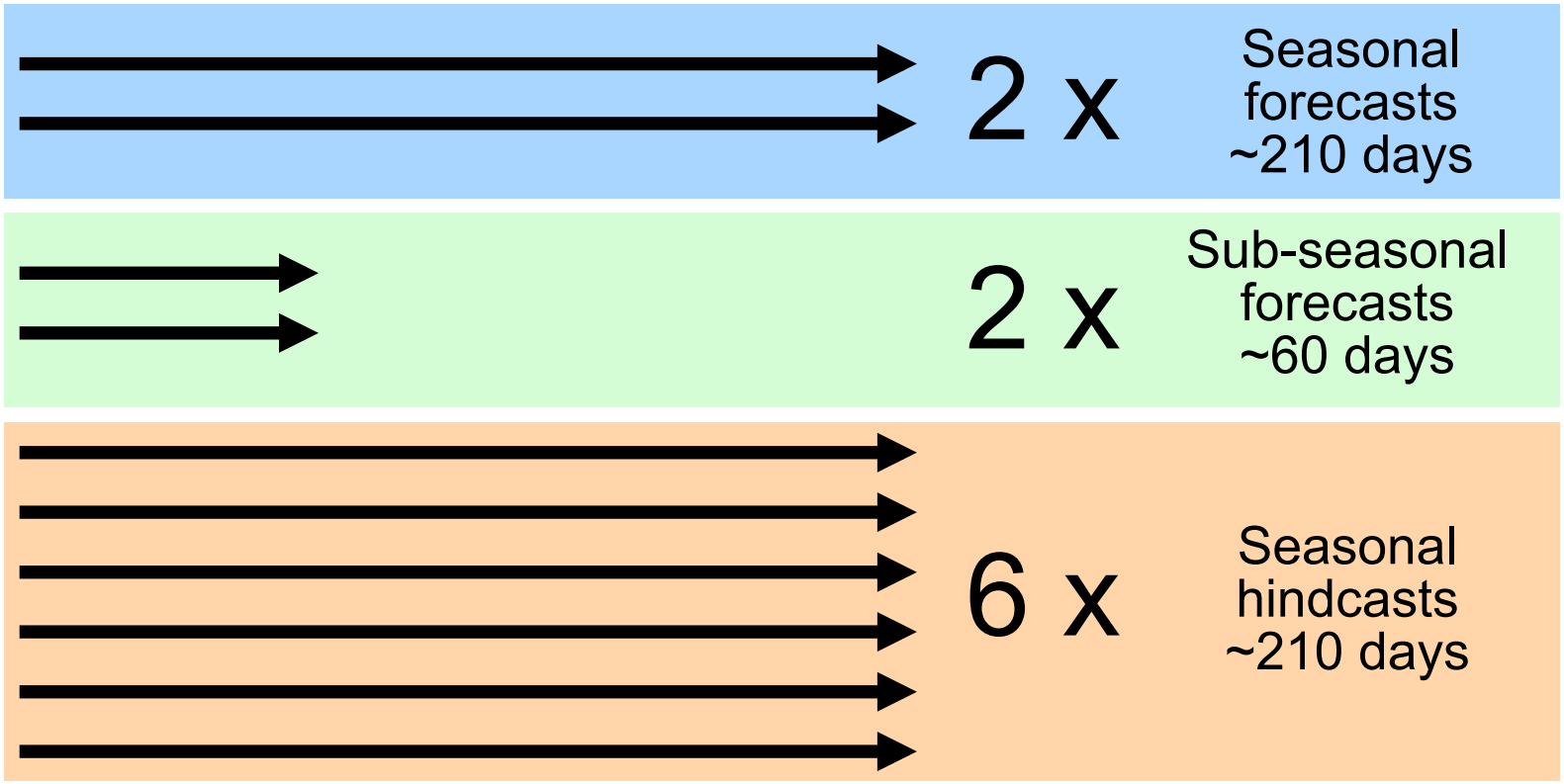
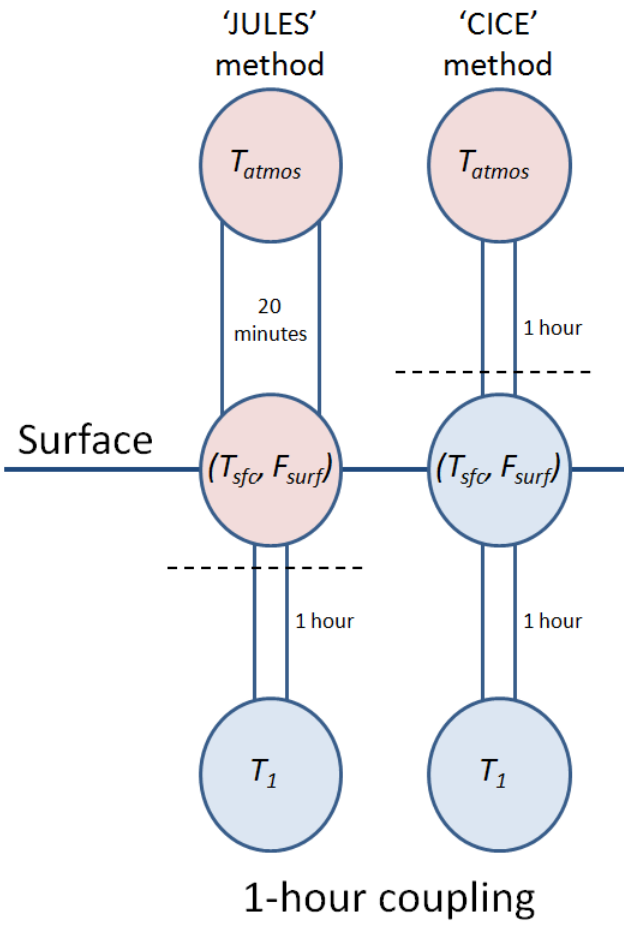
A day in the life of GloSea5



Coupling methodology



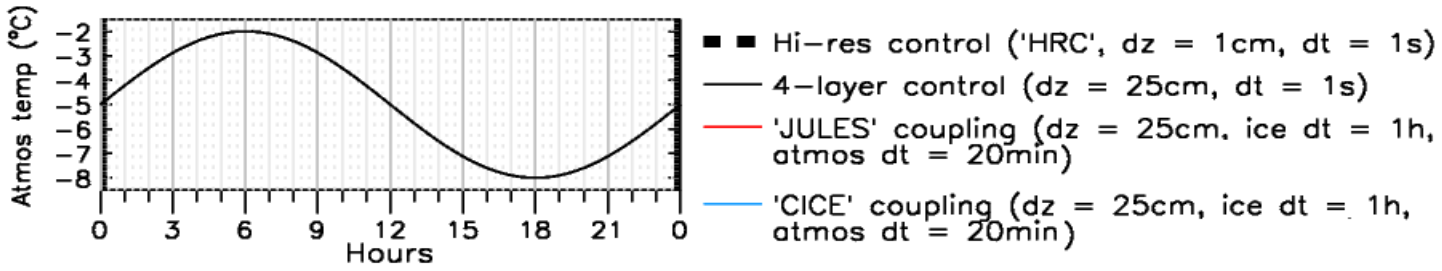
1-hour coupling

- Coupling this way allows us to keep the surface exchanges in JULES
- Means exchanges performed every UM/JULES time step
- Rather than updated every coupling time step
- Exchanges typically 3-10 times more frequent

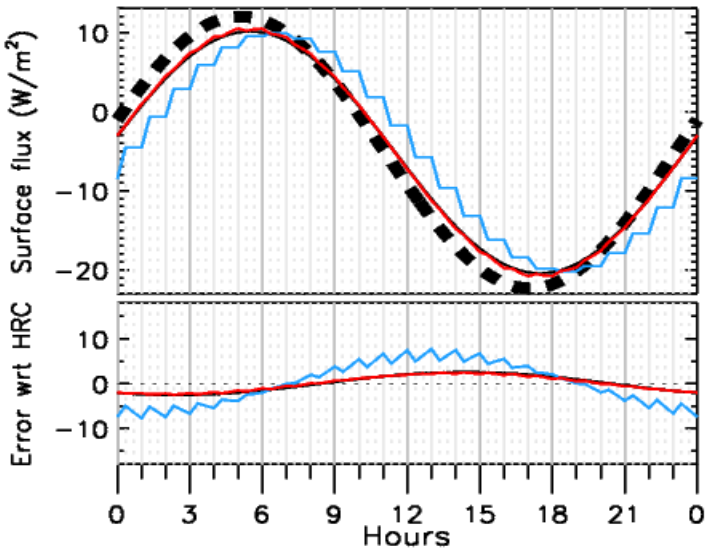
[**West et al., in prep**]

Impact on surface heat flux

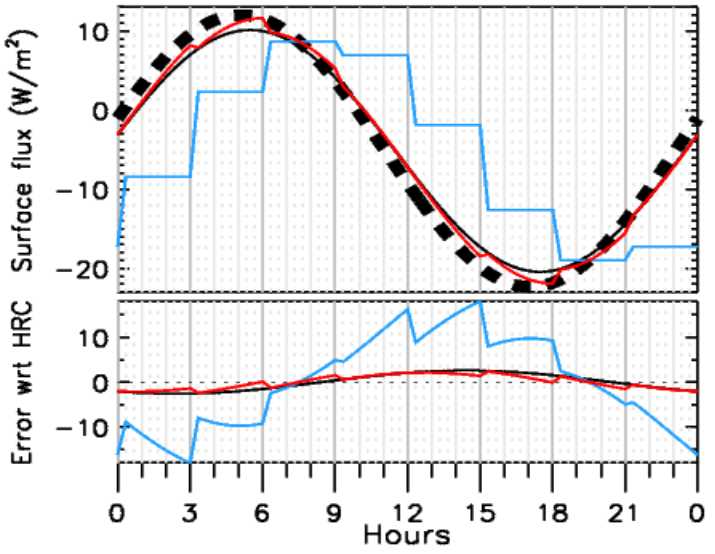
Results from a 1-D idealised study



1-hourly coupling



3-hourly coupling



[West et al., in prep]